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METEOROLOGICAL CONSIDERATIONS IN THE HANDLING OF A MIXTURE OF LIQUID FLUORINE AND LIQUID OXYGEN

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Report Prepared For:

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METEOROLOGICAL CONSIDERATIONS IN THE HANDLING OF A MIXTURE OF LIQUID FLUORINE AND LIQUID OXYGEN

INTRODUCTION

This report has two purposes: primarily it presents a general climatology for the Cape Kennedy-Merritt Island area of those weather elements pertinent to the use of a mixture of liquid fluorine and liquid oxygen, FLOX; and secondly, it outlines questions regarding the behavior of fluorine in the atmosphere. Although the second purpose is treated only briefly, its importance cannot be regarded as secondary because until answers to such questions are obtained, either through experimentation, or more likely through intelligent speculation, specific problem areas arising from the introduction of FLOX into the atmosphere cannot be defined.

The intent is to provide general background information to the Advanced Studies Office, Facilities, Engineering and Construction Division, NASA Kennedy Space Center.

The physical and chemical properties of fluorine and its pertinent compounds are outlined. Some of the problems that could arise should fluorine be introduced into the atmosphere are discussed and recommendations are offered toward the possible solution of these problems.

The general nature of the diffusion of a gas in the atmosphere is discussed briefly and a climatology pertinent to this problem is presented. Also, in the absence of weather observations from Merritt Island, some speculations on possible differences in the weather on Cape Kennedy and on Merritt Island are given.

FLUORINE, PROPERTIES AND PROBLEMS

Fluorine is an extremely powerful oxidant that is highly corrosive to most materials. It is the most active of all elements and combines readily with organic compounds, many metals, and some gases. Fluorine is highly toxic. Toxicity experiments (1) demonstrated that the inhalation of fluorine was generally fatal to the animals used in the tests. Severe damage to the respiratory tract was the only pathology consistently observed. Dermal exposure tests using pure fluorine at a pressure of 40 lbs/in^2 caused the experimenters to liken the burn to that caused by oxyacetylene.

Pure fluorine, contrary to widespread belief, generally reacts slowly with other substances (2). When, however, reaction does occur it is violent, for fluorine develops a very high heat of reaction. Fluorine does react readily with water and water vapor and with petroleum products. The heat involved may be sufficient to cause an uncontrollable reaction. Fluorine boils at -305°F (-187°C), but in the event of a ground spill, the rate of change of fluorine from a liquid state to a gaseous state will depend largely upon the area covered by a given amount of fluorine and by meteorological conditions.

In the presence of even a small amount of moisture, fluorine reacts with hydrogen very rapidly and with violence to form hydrogen fluoride. The molecular weight of monomolecular hydrogen fluoride is 20, somewhat lighter than air, but hydrogen fluoride is subject to considerable molecular aggregation depending upon temperature and pressure so that at normal atmospheric pressure and temperatures of 60° to 70°F the effective molecular weight is closer to 50, which is heavier than air.

Hydrogen fluoride is toxic, but not as toxic as fluorine (1). Animals exposed to hydrogen fluoride in concentrations of 33 ppm and 8.6 ppm for a total of 166 hours over a five-week period suffered ulcerations and other aberrations, but only the smallest animals, rats and mice, died. Under the conditions of this experiment it was proposed that tolerable exposure concentrations for fluorine and hydrogen fluoride were 1 ppm and 7 ppm respectively.

Also important is the effect of fluorine and hydrogen fluoride on plant life (3, 4, 5). Not only may plants contaminated with fluorides be severely damaged, but contaminated vegetation may find its way, either directly or indirectly, into the food supply possibly inflicting injurious effects upon the consumer.

Dermal exposure experiments conducted using a 47 percent solution of hydrogen fluoride resulted in chemical burns that healed in about 27 days, taking about twice as long to heal as the fluorine burns, which were classified as thermal burns (1).

The boiling point of anhydrous hydrogen fluoride is 67°F (19.5°C) but aqueous hydrogen fluoride (hydrofluoric acid) has a higher boiling point that is dependent upon the concentration of the solution and which may be as high as 230°F (110°C).

Fluorine added to water yields hydrofluoric acid, hydrogen peroxide, oxygen, and fluorine monoxide. Fluorine also displaces, but does not react with chlorine. Compounds containing both fluorine and nitrogen are formed only with difficulty.

The information above, which outlines some of the properties and characteristics of fluorine and which also lists the reactions of fluorine with the major constituents of the atmosphere, is known to those working with fluorine, but this information is included here as a background for the material to follow. Certainly in light of the preceding discussion questions arise that must be answered before this climatological material can be effectively used.

Considering the diffusion process of a fluorine spill there are two obvious questions: (1) What is the maximum allowable concentration, and (2) what will be the configuration of the pollutant under various atmospheric and release conditions? Toxicity experiments using fluorine and hydrofluoric acid provide some basis for establishing the maximum allowable concentration, but the second question is more difficult to answer.

Release circumstances may be many and varied. The size of the release may be large, or small; the release may occur near ground level or at considerably greater heights; the oxidant may be released with or without fuel; and the release may occur during a long time period, or during a time period so short as to be considered instantaneous. Atmospheric conditions at the time of release may also vary considerably. The atmosphere may be stable, or unstable; the wind may be steady or variable, strong or weak; moisture may occur in varying amounts and distributions.

Presumably a large spill coincident with a moist atmosphere would result in a violent reaction that would send a fireball, or hot buoyant cloud, upward to hundreds or perhaps thousands of feet. After the turmoil of the explosion, what is the overall configuration of the pollutants? Residuals from the primary reaction might possibly be left near ground levels. What is the importance of these residuals? With what release types and atmospheric conditions can we expect the pollutant to remain near ground level? If a FLOX line were to rupture spilling liquid fluorine and liquid oxygen on the ground, a knowledge of the evaporation rate of fluorine is essential in the determination of the source strength of a given spill. With given atmospheric conditions and spill areas, what is the evaporation rate of liquid fluorine into the atmosphere? Would some of the fluorine replace the chlorine in salt particles, abundant in a marine environment, to form sodium fluoride, a toxic salt? How much hydrogen fluoride would the sodium fluoride absorb? Of what importance is this?

There are many combinations of atmospheric conditions and release types which would result in different cloud configurations. It is not within the scope of this report to attempt a description of the possible configurations, but the behavior of fluorine in the free atmosphere is a problem of major magnitude and one which should be thoroughly investigated by a group consisting of biologists, chemists, physicists, and meteorologists in order to postulate the ramifications involved with the use of fluorine.

WEATHER ELEMENTS PERTAINING TO THE DIFFUSION AND TRANSPORT OF A GAS

The transport and diffusion of a gas in the free atmosphere is dependent upon the wind and the atmospheric diffusivity. The wind speed determines the rate at which the gas will be transported. The wind direction determines the sector which might be affected by the passage of a gas.

Atmospheric diffusivity is dependent upon wind variability and the stability of the atmosphere. Low-level stability results in poor diffusion while instability aids diffusion. Variable wind directions also promote diffusion.

In the case of a low-level release, desirable weather characteristics would normally be high wind speeds, large fluctuations in the wind direction, and an unstable atmosphere. In the case of an elevated release, under certain conditions a stable atmosphere might be desirable in order that pollutants could be transported away from the area without reaching the ground. It must be understood, however, that optimum weather conditions may vary widely depending upon the location of the areas to be protected relative to the release point.

DATA SOURCE

Published climatological statistics for the Cape Kennedy-Patrick Air Force Base area are abundant (6, 7, 8, 9), but generally are either in a form not easily used for this particular problem, or are based upon observations taken at Patrick Air Force Base. The climatology that follows is based upon data collected at the Cape Kennedy Weather Station between May 1950 and July 1962. Prior to 1957 there were interruptions in the data and not all the information presented here is based on data from the entire period. The Air Force Cambridge Research Laboratories are preparing a summary of meteorological data collected from the WIND system at Cape Kennedy. The WIND system is a network of meteorologically instrumented towers now in continuous operation and fully described elsewhere (10). The summary, soon to be completed, is based upon observations collected over a span of only one year, but nevertheless will be useful for general planning purposes. In the climatology that follows the above study will be referred to as the AFCRL WIND summary.

Except for data from the WIND network, tabulations included in this study are based on at least six years data.

CLIMATOLOGY

The figures and tables presented here are largely self-explanatory and need little interpretation, but the more important features are discussed and opinions are offered as to the possible climatological differences between Cape Kennedy and Merritt Island.

SURFACE WINDS

Table 1 shows the mean vector surface winds and vector standard deviations during the course of the day. Tables 1a and 1b show that except for short periods of time the mean vector winds are from the easterly quadrant from April through October. Speeds are generally light during hours of darkness increasing to a mid-afternoon maximum and then slowly subsiding afterward. From December through February prevailing surface winds in the Cape Kennedy area are from the northwest quadrant. During these months maximum vector wind speeds occur at night.

A tabulation of wind rose data by hour and month for the available continuous period of record of hourly observations from the Cape Kennedy Weather Station (October 1956 through May 1964) shows some differences in the wind distribution from that given in Tables 1a and 1b, but these differences are not generally significant for planning purposes (11).

As a part of the AFCRL WIND summary, the standard deviation of the wind direction was computed for winds observed at the 12-foot level of Towers 700 and 302. Tower 700 is located near the eastern shoreline of Cape Kennedy and Tower 302 is approximately four miles southwest of Tower 700 and four miles west of the Atlantic Ocean. In all months data from the inland location exhibited greater directional variability than did the coastal data. The greatest differences in the standard deviations of wind direction at these two locations occurred during the early afternoon hours, the time of the maximum sea breeze component.

Figure 1 was constructed from the information contained in Table 1 and illustrates a method by which that information may be readily visualized. Figure 1a shows the March mean vector winds for the eight time periods. Figure 1b shows the resultant, or mean vector wind, and vector standard deviation of the surface wind between 0000 and 0259 LST for March. The mean vector wind for this time period is from 212 degrees at 2.8 knots. The vector standard deviation is 6.9 knots so that about 63 percent of all winds observed for the above month and time period will originate within the dashed circle.

Figure 2 consists of standard wind roses and as such are self-explanatory.

An investigation of sea breeze characteristics by personnel at Patrick Air Force Base suggests that under sea breeze conditions winds on Merritt Island may be slightly lighter and may also come from a more clockwise direction than those winds on Cape Kennedy.

FOG

A fluorine spill with fog present could be a very hazardous condition. Fog is generally associated with poor diffusivity and ample moisture would be available to react with the fluorine. The result would be hydrogen fluoride suspended in fog that could persist for several hours, covering a large area.

In the Cape Kennedy-Merritt Island area the most frequent fog type is radiation fog that has formed on the mainland and is then transported to the Cape area by westerly or northwesterly winds. Radiation fog that forms in the Cape area is not a frequent occurrence, but when it does form the result is a ground fog perhaps six feet in depth. Frontal fog, generally accompanied by a light rain, is an important fog type found in the Cape Kennedy area. This fog occurs in the winter north of an east-west oriented cold front south of the Cape area. Such fog may persist for two or three days and is sometimes accompanied by strong easterly winds. Tables 2 and 3 and Figure 3 are based upon observations taken at the Cape Kennedy Weather Station and include only those times when fog restricted the prevailing visibility to six miles or less.

Fog occurs mainly during the months of December, January, and February. During these months over 60 percent of annual fog occurrences are observed. The total number of occurrences from April through October is small.

Table 2a shows the percentage frequency of fog occurrences by time of day for each month. Table 2b shows the percentage frequency of fog occurrences by months. The heavy lines within Table 2a outline the hours during which at least 50 percent of the observed fog occurred. The lower heavy line represents the time of day when fog is most frequent. The foggiest time of day from November through March is about 0700 LST with the majority of fog cases occurring in a time period of four to seven hours.

WIND COINCIDENT WITH FOG

Table 3 and Figure 3 show the distribution of surface winds when fog was observed. The most frequent wind direction coincident with fog is from the north through the west with 46 percent of the cases occurring with winds from these directions. Only 11.5 percent of the fog cases occurred when the wind direction was north northeast through south southeast. Calm winds account for over 24 percent of the cases so it is evident that the preponderance of fog occurrences are associated with winds from the northwest quadrant and with calms, which in this case are all wind speeds two knots or less.

During February, March, and April, fog occurs frequently with southerly winds and during March there is a high incidence of easterly winds with fog.

With fog conditions wind speeds are generally in the lower speed range. Two-thirds of all cases occurred with wind speeds in the 3 to 12 knot range and almost one-fourth the cases occurred with calm winds. Fog occurring with easterly winds is the frontal type fog and wind speeds tend to be high. In March over 50 percent of the easterly wind cases were associated with speeds ranging between 13 and 20 knots.

The 19-year record at Daytona Beach, Florida indicates a fog frequency three times that of Cape Kennedy and most of this fog is the radiation type. Merritt Island, with its relatively large land mass, more than likely would also realize more radiation fog than Cape Kennedy. Being closer to the Florida mainland, Merritt Island would also experience fog that is advected from the mainland, but that never reaches the Cape area.

PRECIPITATION AND THUNDERSTORMS

Rain coincident with a fluorine spill would be important, but hydrogen fluoride would be precipitated, thus tending to confine harmful effects to a relatively small area. Also, hydrogen fluoride would undergo dilution which would tend to minimize the harmful effects.

Rainfall in the Cape Kennedy area is generally associated with frontal activity or convective activity. A small percentage of rain occurs from tropical storm activity. The rainy season occurs from June through October when about 60 percent of the total annual rainfall occurs.

Table 4 shows the normal monthly and annual rainfall and the percentage frequency of rain occurrence at Cape Kennedy.

Table 5a shows the percentage frequency of thunderstorm occurrence by time of day and Table 5b shows the percentage frequency of thunderstorm occurrence by month. The area within the heavy line in Table 5a indicates the hours during which at least 50 percent of all thunderstorms for these months occur.

Rainfall amounts on Merritt Island during June, July, and August, months of maximum convective activity, may be somewhat larger than on Cape Kennedy.

VERTICAL TEMPERATURE PROFILE

As part of the WIND program the vertical temperature difference, ΔT, is measured between 54 feet and 6 feet and between 162 feet and 54 feet. When the temperature at the higher level is greater than the temperature at the lower level, the lower atmosphere is defined as stable. Negative values, or cooler temperatures at the higher levels, indicate unstable conditions. The degree of stability or instability is determined by the magnitude of the temperature difference. Data from the 54 foot and 6 foot sensors compiled by AFCRL for the WIND summary indicate that at Cape Kennedy the period of greatest instability occurs at approximately 1300 LST and has the greatest intensity during the summer months. The period of instability varies from about 11 hours duration, beginning between 0700 and 0800 LST, in the summer months, to about 9 hours duration, beginning shortly after 0800 LST, in the winter. The period of greatest stability occurs between midnight and 0600 LST and is most pronounced during the winter.

Figure 4 is a schematic depiction of the low-level stability related to time of day. Figure 5 and Table 6 are summaries of data obtained during the Ocean Breeze diffusion experiments, June 1961 to January 1962. These figures were taken directly from the report of that project (10).

Figure 5 shows the magnitude and range of ΔT within one standard deviation, σ, about the mean for various wind speed intervals. In addition, the standard error, SE, of the mean ΔT is given for each wind speed interval. Table 6 shows that for the four times of day considered, midnight and sunrise are predominantly stable periods while noontime is predominantly unstable.

The vertical temperature profile on Merritt Island is not expected to differ substantially from that on Cape Kennedy.

SURFACE TEMPERATURES AND DEW POINTS

Free air temperatures and dew point temperatures will affect the rate at which liquid fluorine will evaporate into the atmosphere if a spill of relatively small magnitude should occur. Given similar wind conditions and spill areas, the evaporation rate varies directly with the free air temperature and inversely with the dew point temperature.

Since the dew point temperature is a measure of the water vapor content in the atmosphere, it is also an indication of the amount of hydrogen present. High dew points would then suggest a rapid reactive rate between fluorine and hydrogen, and a high percentage of fluorine going into reaction.

It is seen from Table 7 that the mean vapor pressure during the month of January is .410 lbs. per square inch and in August is .863 lbs. per square inch. In the mean about twice as much moisture is available during August as during January and it would be during these times of high vapor pressure that reactions between fluorine and hydrogen would be the most violent.

Moisture content may also determine the ratio of aqueous hydrogen fluoride to anhydrous hydrogen fluoride. This may or may not be pertinent to the problem of containing a spill, but it is conceivable that under certain atmospheric conditions liquid aqueous hydrogen fluoride would be present with gaseous anhydrous hydrogen fluoride thus possibly complicating containment problems. Temperature data in Table 7 and from the AFCRL WIND summary indicate that if anhydrous hydrogen fluoride resulted from a spill it would likely be liquid during the night and early morning hours during the months of November through April because in the mean temperatures are less than 67°F, the boiling point of anhydrous hydrogen fluoride.

It is doubtful that important temperature and dew point temperature differences exist, in the mean, between Merritt Island and Cape Kennedy, but when the sea breeze is confined to the immediate coastal area temperatures may be 5 to 10 degrees higher on Merritt Island for short periods of time.

CLOUDINESS

If a release of FLOX into the atmosphere should occur, the cloud, or fireball, will assume a configuration that is dependent upon the size of the release, the elevation of the release, and the span of time over which the release was accomplished. If, for any reason, the cloud reaches heights of more than a few hundred feet, cloudiness becomes an important weather element.

Table 8 shows the annual percentage frequency of cloud ceilings at various heights over Cape Kennedy with respect to surface wind direction. A ceiling exists when six-tenths or more of the sky is covered by clouds. Ceilings of 1000 feet or lower occur with a frequency of about two percent. As in the case of fog, the low ceilings are associated with surface winds blowing from the northwest quadrant and, from tables not shown, (7), occur mainly in December, January, and February. Ceiling heights of 3100 to 10,000 feet occur with a frequency of 12.7 percent. Ceilings in this height range are predominantly associated with surface winds from the north through the southeast directions.

Except for the increase of convective clouds during June, July, and August, cloudiness over Merritt Island probably differs little from that found over the Cape area.

SUMMARY

Fluorine is a highly toxic and corrosive gas, the safe handling of which requires the utmost care. Fluorine is the most reactive of all elements and combines readily with atmospheric moisture to form hydrogen fluoride. Hydrogen fluoride is considerably less toxic than fluorine, but is very corrosive.

Optimum weather conditions for the diffusion of FLOX are difficult to define exactly because at this time little is known about the characteristics of the cloud, or fireball, once a release occurs. If it is assumed that the cloud will conform to the characteristics of a ground level release, then the following weather conditions would provide optimum release conditions:

1. Unstable atmosphere
2. Variable winds blowing away from populated areas and preferably offshore
3. Rain

The high moisture content would permit all released fluorine to react forming the less toxic hydrogen fluoride while the offshore winds carried the corrosive acid toward the ocean. In the mean these conditions are most likely to occur during the months of December and January between 0800 LST and 1500 LST. During other times and other months mean conditions are generally such that the lower levels are stable or winds are onshore.

If, on the other hand, a catastrophic spill occurs, it is likely that the resulting cloud, or fireball, would assume the characteristics of an elevated, instantaneous release. This would occur because the high temperatures of reaction with hydrogen and the buoyancy of hydrogen fluoride would displace the cloud upwards at a rapid rate, penetrating and temporarily destroying any low-level inversion. Under these circumstances optimum weather conditions would be:

1. Stability in the lower levels
2. Offshore winds
3. High moisture content from surface to pollutant level

In the mean these conditions are more likely during the night-time hours in the months of December through March. From April through November low-level winds are predominantly on-shore and during the summer months atmospheric instability is strongest and is of longest duration.

The climatology presented here suggests a location for FLOX storage facilities that is isolated from populated areas, orchards or costly structures, particularly in the northwest and southeast quadrants. In general, these are the directions of the prevailing winds and the strongest winds. Fog and low ceilings occur most frequently with winds from the northwest quadrant.

If it is reasonable to assume that the reaction rate of fluorine with water vapor and the amount of fluorine going into reaction with water vapor varies directly with atmospheric vapor pressure, then dew point temperatures are of importance in considering the problem of spill containment. High dew points, generally occurring in the summer months, would tend to be associated with more violent reactions than would occur during the winter under similar release conditions. Also, during the summer months the pollutant would consist of a higher percentage of hydrogen fluoride than during the winter months.

CONCLUSION

At this time little is known about the behavior of fluorine in the free atmosphere. These behavioral characteristics are important in the determination and use of the meteorological parameters pertinent to the FLOX problem.

Before the climatology presented here can be used effectively and before a climatology of all meteorological elements essential to the fluorine problem can be assembled, it is recommended the following problems be subjected to intense investigation:

1. Determine the configuration and stratification of the pollutants and which combinations of meteorological parameters offer the best, and worst, diffusivity climate for the following release types:

    a. A catastrophic release
    b. A release due to the malfunction of ground equipment
    c. Normal rocket firing

2. Determine the reaction rate between fluorine and hydrogen and the range of concentration of hydrogen fluoride when the moisture content of the atmosphere is varied.

3. Determine evaporation rates of liquid fluorine under varying meteorological conditions.

4. Fluorine displaces chlorine from salt to form sodium fluoride. Sodium fluoride absorbs hydrogen fluoride. Determine the significance of this reaction.

5. Determine the effects of a long-term addition of fluorides into the soil and vegetation on Cape Kennedy and Merritt Island.

6. Determine the maximum allowable concentration of fluorine and hydrogen fluoride.

The determination of the configurations a pollutant might assume with various meteorological parameters is in itself a major problem and one that does not lend itself to a simple solution. One approach might be to study pictures taken of various releases when weather conditions are known. Configuration models thus obtained could be subjectively modified to account for the presence of fluorine. Controlled scale tests would also be useful in formulating configuration models. Regardless of the way in which this problem is approached, considerable speculation will be required.

The solution to problems 2, 3 and 4 can be determined experimentally.

The addition of fluorides to soils and vegetation has been the subject of numerous studies (3, 4, 5). The general methods of previous studies could probably be utilized in a study of the Cape Kennedy-Merritt Island area.

Tests already conducted (1) provide a basis for the determination of the maximum allowable concentration.

The behavior of fluorine in the free atmosphere presents problems of major importance. In order to best postulate the ramifications involved with the use of fluorine it is recommended that these problems be thoroughly investigated by a group of biologists, chemists, physicists and meteorologists chosen from those organizations concerned with fluorine and its use.

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Mr. Kenneth M. Nagler, Head, Spaceflight Meteorology Group, National Weather Satellite Center, U. S. Weather Bureau, Washington, D. C., contributed substantially to this report. Besides directing the overall effort, Mr. Nagler contributed many specific ideas as to how the problem should be approached.

LOCAL TIME

	0000-0259	0300-0559	0600-0859	0900-1159	1200-1459	1500-1759	1800-2059	2100-2359	
α	282	298	295	278	312	099	117	209	
V	1.8	2.3	2.5	2.2	0.5	1.0	0.9	0.7	January
σ	6.7	7.1	8.0	9.0	12.1	9.7	7.4	8.0	
α	255	295	325	030	040	031	069	192	
V	0.6	1.1	1.1	0.8	2.0	1.0	0.5	0.6	February
σ	7.4	7.7	8.4	11.2	12.9	10.8	7.6	8.2	
α	212	225	249	224	122	138	021	179	
V	2.8	2.6	2.0	1.2	1.1	2.1	2.9	3.2	March
σ	6.9	7.1	8.4	11.3	12.1	11.7	9.6	8.0	
α	143	131	122	101	089	081	103	114	
V	1.7	1.6	1.1	2.6	4.3	4.8	3.5	2.8	April
σ	8.4	7.3	9.2	11.4	11.1	11.3	8.4	8.4	
α	155	176	167	111	101	104	129	137	
V	1.9	0.9	0.9	2.9	6.4	6.9	3.6	3.1	May
σ	6.4	6.6	7.8	9.1	10.1	9.8	7.5	7.1	
α	182	207	210	125	111	120	147	160	
V	3.5	2.0	1.7	2.6	6.7	7.0	4.4	3.7	June
σ	4.8	4.5	6.3	8.7	8.5	8.2	6.4	5.5	

TABLE 1a. Surface mean vector wind and vector standard deviation during the course of the day at Cape Kennedy, Florida. Wind direction, α, is the direction from which the wind is blowing. Wind speed, in knots, is denoted by V. The unit of the vector standard deviation, σ, is knots.

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LOCAL TIME

	0000-0259	0300-0559	0600-0859	0900-1159	1200-1459	1500-1759	1800-2059	2100-2359	
α	173	184	179	131	117	123	142	148	
V	2.7	1.6	1.9	4.2	6.9	5.8	3.0	3.7	July
σ	8.4	4.6	5.5	7.3	7.8	7.1	6.7	4.9	
α	159	204	117	115	104	113	139	144	
V	1.3	1.2	1.7	3.6	5.9	4.3	3.0	2.4	August
σ	5.6	5.9	5.9	8.2	9.9	8.6	6.5	5.9	
α	108	103	093	094	085	089	094	111	
V	3.9	2.9	3.1	4.7	6.2	5.9	5.1	5.2	September
σ	7.5	7.2	7.6	9.1	9.8	8.5	7.6	7.0	
α	045	036	034	035	038	034	045	058	
V	4.5	4.4	4.6	5.9	6.1	6.5	5.3	4.4	October
σ	7.4	8.2	8.6	9.8	10.2	8.7	8.2	8.0	
α	043	048	323	353	005	007	009	360	
V	1.5	2.4	2.5	3.4	3.4	2.9	2.2	1.2	November
σ	8.2	8.4	8.4	10.4	10.5	10.4	8.0	8.1	
α	270	277	283	284	291	136	346	242	
V	1.5	1.8	2.1	1.7	0.8	0.2	0.4	0.8	December
σ	8.7	8.1	7.8	10.4	10.8	8.8	7.3	7.3	

TABLE 1b. Surface mean vector wind and vector standard deviation during the course of the day at Cape Kennedy, Florida. Wind direction, α , is the direction from which the wind is blowing. Wind speed, in knots, is denoted by V. The unit of the vector standard deviation, σ , is knots.

Hour LST	J	F	M	A	M	J	J	A	S	O	N	D
00	9.2	3.1	1.6	.8	0	0	0	0	0	.4	2.4	5.5
01	10.8	5.3	3.2	.8	.8	0	0	0	0	.4	2.0	5.1
02	12.8	7.2	3.2	1.7	1.2	2.1	.4	1.2	.4	2.0	2.0	5.5
03	13.9	8.4	3.6	2.5	1.2	2.1	.4	.8	0	2.0	5.2	6.3
04	13.5	12.3	4.8	3.3	2.4	2.1	.4	2.4	1.2	2.3	6.4	6.7
05	15.3	13.1	5.6	3.7	4.8	2.1	1.2	3.1	2.8	3.8	5.4	7.4
06	17.8	13.9	6.0	5.2	7.0	4.5	.8	4.6	4.0	4.5	6.2	7.8
07	17.8	18.5	9.1	3.1	2.1	.7	0	1.4	1.8	2.9	8.2	8.3
08	12.7	14.5	5.6	1.7	.7	.4	0	.3	.7	1.1	3.2	6.5
09	7.3	5.1	4.4	1.1	.7	0	0	0	.7	.3	1.4	4.0
10	4.3	2.4	2.6	.3	.3	0	0	0	.4	.7	.4	2.9
11	2.3	1.2	1.4	0	0	0	0	0	.4	.7	.4	1.5
12	1.5	1.6	1.9	0	0	0	0	0	.4	.7	0	1.1
13	.3	.8	1.5	0	0	0	0	0	0	.3	0	.4
14	.3	.4	.8	0	0	0	0	0	0	.4	0	.4
15	0	.8	1.1	0	0	0	0	0	0	.4	0	1.1
16	0	.4	.8	0	0	0	0	0	0	.4	0	1.5
17	.4	.4	1.2	0	0	0	0	0	0	.4	0	1.6
18	2.0	.9	2.0	0	0	0	0	0	0	.4	.4	1.6
19	1.6	.4	2.8	0	0	0	0	0	0	.4	.4	.4
20	2.4	1.8	2.4	0	0	0	0	0	0	.4	.8	1.6
21	3.2	1.2	1.6	0	.4	0	0	0	0	0	1.6	2.4
22	6.0	1.2	2.0	0	0	0	0	0	0	0	1.6	4.8
23	7.6	2.7	1.2	0	0	0	0	0	0	0	1.6	4.8

TABLE 2a. Hourly percentage frequency of fog occurrence by month at Cape Kennedy, Florida.

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Percentage Frequency	6.7	5.0	2.9	1.0	0.9	0.6	0.1	0.6	0.5	1.0	2.1	3.7	2.1

TABLE 2b. Monthly percentage frequency of fog occurrence, Cape Kennedy, Florida

Wind Direction	Calm	Wind Speed (knots) 3-12	13-20	20	Total Frequency	Percent Frequency
N		81	9		90	7.1
NNE		13			13	1.0
NE		9			9	.7
ENE		11	2	2	15	1.2
E		16	21	3	40	3.2
ESE		16	5		21	1.7
SE		16	3		19	1.5
SSE		21	7		28	2.2
S		92	11		103	8.1
SSW		41	1		42	3.3
SW		42			42	3.3
WSW		46			46	3.6
W		94			94	7.4
WNW		84	4		88	6.9
NW		157	15		172	13.6
NNW		105	34	1	140	11.0
Calm	306				306	24.2
Tot. Freq.	306	844	112	6	1268	
Percent Frequency	24.2	66.5	8.8	.5		100.0

TABLE 3a. Distribution of surface winds coincident with fog at Cape Kennedy, Florida. ANNUAL

Wind Direction	Calm	Wind Speed (knots) 3-12	13-20	20	Total Frequency	Percent Frequency
N		39			39	12.7
NNE		1			1	.3
NE		1			1	.3
ENE		3	1		4	1.3
E		4	5		9	2.9
ESE		3			3	1.0
SE						
SSE		3	4		7	2.3
S		20			20	6.5
SSW		16			16	5.2
SW		21			21	6.9
WSW		9			9	2.9
W		23			23	7.5
WNW		15			15	4.9
NW		30	4		34	11.1
NNW		28	1		29	9.4
Calm	76				76	24.8
Tot. Freq.	76	216	15	0	307	
Percent Frequency	24.8	70.3	4.9	0		100.0

TABLE 3b. Distribution of surface winds coincident with fog at Cape Kennedy, Florida. JANUARY

Wind Direction	Calm	Wind Speed (knots) 3-12	13-20	20	Total Frequency	Percent Frequency
N		10	3		13	6.5
NNE		3			3	1.5
NE		2			2	.5
ENE						
E		3			3	1.5
ESE		1	1		2	1.0
SE		5			5	2.5
SSE		3	2		5	2.5
S		28	6		34	16.7
SSW		8			8	3.9
SW		6			6	3.0
WSW		10			10	4.9
W		13			13	6.4
WNW		13			13	6.4
NW		22	2		24	11.8
NNW		12	12		24	11.8
Calm	39				39	19.1
Tot. Freq.	39	139	26	0	204	
Percent Frequency	19.1	68.2	12.7	0.0		100.0

TABLE 3c. Distribution of surface winds coincident with fog at Cape Kennedy, Florida. FEBRUARY

Wind Direction	Calm	Wind Speed (knots) 3-12	13-20	20	Total Frequency	Percent Frequency
N		4	5		9	6.3
NNE		5			5	3.5
NE		2			2	1.4
ENE		3	1	2	6	4.2
E		5	9	3	17	11.8
ESE		3			3	2.1
SE		3	1		4	2.8
SSE		2	1		3	2.1
S		18	5		23	15.9
SSW					1	.7
SW		2			2	1.3
WSW		4			4	2.8
W		10			10	6.9
WNW		9	1		10	6.9
NW		11	2		13	9.0
NNW		9	4		13	9.1
Calm	19				19	13.2
Tot. Freq.	19	90	30	5	144	
Percent Frequency	13.2	62.5	20.8	3.5		100.0

TABLE 3d. Distribution of surface winds coincident with fog at Cape Kennedy, Florida. MARCH

Wind Direction	Calm	Wind Speed (knots) 3-12	13-20	20	Total Frequency	Percent Frequency
N		1			1	1.7
NNE						
NE						
ENE						
E						
ESE		1	1		2	3.4
SE		6	1		7	12.0
SSE		8			8	13.8
S		8			8	13.8
SSW		4			4	6.9
SW		3			3	5.2
WSW						
W		4			4	6.9
WNW						
NW		2			2	3.5
NNW		2			2	3.5
Calm	17				17	29.3
Tot. Freq.	17	39	2	0	58	
Percent Frequency	29.3	67.2	3.5	0.0		100.0

TABLE 3e. Distribution of surface winds coincident with fog at Cape Kennedy, Florida. APRIL

Wind Direction	Calm	Wind Speed (knots) 3-12	13-20	20	Total Frequency	Percent Frequency
N		1			1	2.2
NNE						
NE						
ENE						
E		1			1	2.2
ESE						
SE						
SSE		2			2	4.5
S		4			4	8.9
SSW		2			2	4.4
SW		2			2	4.4
WSW		3			3	6.7
W		4			4	8.9
WNW		1			1	2.2
NW		5			5	11.1
NNW		3			3	6.7
Calm	17				17	37.8
Tot. Freq.	17	28	0	0	45	
Percent Frequency	37.8	62.2	0.0	0.0		100.0

TABLE 3f. Distribution of surface winds coincident with fog at Cape Kennedy, Florida. MAY

Wind Direction	Calm	Wind Speed (knots) 3-12	13-20	20	Total Frequency	Percent Frequency
N		4			4	13.8
NNE						
NE						
ENE						
E						
ESE						
SE		1			1	3.4
SSE						
S						
SSW						
SW						
WSW		2			2	6.9
W		1			1	3.5
WNW		2			2	6.9
NW						
NNW		3			3	10.3
Calm	16				16	55.2
Tot. Freq.	16	13	0	0	29	
Percent Frequency	55.2	44.8	0.0	0.0		100.0

TABLE 3g. Distribution of surface winds coincident with fog at Cape Kennedy, Florida. JUNE

Wind Direction	Calm	Wind Speed (knots) 3-12	13-20	20	Total Frequency	Percent Frequency
N						
NNE						
NE						
ENE						
E						
ESE						
SE						
SSE						
S						
SSW						
SW						
WSW						
W						
WNW						
NW						
NNW						
Calm	4				4	100.0
Tot. Freq.	4	0	0	0	4	
Percent Frequency	100.0	0.0	0.0	0.0		100.0

TABLE 3h. Distribution of surface winds coincident with fog at Cape Kennedy, Florida. JULY

Wind Direction	Calm	Wind Speed (knots) 3-12	13-20	20	Total Frequency	Percent Frequency
N		1			1	3.9
NNE		1			1	3.9
NE						
ENE						
E						
ESE		1			1	3.9
SE		1			1	3.8
SSE						
S		1			1	3.8
SSW						
SW						
WSW		1			1	3.8
W		3			3	11.5
WNW						
NW		2			2	7.7
NNW						
Calm	15				15	57.7
Tot. Freq.	15	11	0	0	26	
Percent Frequency	57.7	42.3	0.0			100.0

TABLE 3i. Distribution of surface winds coincident with fog at Cape Kennedy, Florida. AUGUST

Wind Direction	Calm	Wind Speed (knots) 3-12	13-20	20	Total Frequency	Percent Frequency
N						
NNE						
NE		1			1	4.2
ENE						
E						
ESE						
SE						
SSE						
S						
SSW		1			1	4.2
SW		1			1	4.2
WSW						
W						
WNW		1			1	4.2
NW		11			11	45.8
NNW		3	2		5	20.8
Calm	4				4	16.6
Tot. Freq.	4	18	2	0	24	
Percent Frequency	16.6	75.0	8.4	0.0		100.0

TABLE 3j. Distribution of surface winds coincident with fog at Cape Kennedy, Florida. SEPTEMBER

Wind Direction	Calm	Wind Speed (knots) 3-12	13-20	20	Total Frequency	Percent Frequency
N		4			4	8.2
NNE						
NE		1			1	2.0
ENE						
E		2			2	4.1
ESE		4	3		7	14.3
SE						
SSE						
S						
SSW						
SW						
WSW						
W		4			4	8.2
WNW		4			4	8.2
NW		13	2		15	30.6
NNW		3			3	6.1
Calm	9				9	18.3
Tot. Freq.	9	35	5	0	49	
Percent Frequency	18.3	71.5	10.2	0.0		100.0

TABLE 3k. Distribution of surface winds coincident with fog at Cape Kennedy, Florida. OCTOBER

Wind Direction	Calm	Wind Speed (knots) 3-12	13-20	20	Total Frequency	Percent Frequency
N		3			3	1.9
NNE		1			1	.6
NE						
ENE		2			2	1.3
E						
ESE		2			2	1.3
SE			1		1	.6
SSE		2			2	1.3
S		7			7	4.4
SSW		6			6	3.8
SW		3			3	1.9
WSW		6			6	3.8
W		17			17	10.7
WNW		23	1		24	15.1
NW		26	1		27	16.9
NNW		12	4		16	10.0
Calm	42				42	26.4
Tot. Freq.	42	110	7	0	159	
Percent Frequency	26.4	69.2	4.4	0.0		100.0

TABLE 31. Distribution of surface winds coincident with fog at Cape Kennedy, Florida. NOVEMBER

Wind Direction	Calm	Wind Speed (knots) 3-12	13-20	20	Total Frequency	Percent Frequency
N		14	1		15	6.9
NNE		2			2	.9
NE		2			2	.9
ENE		3			3	1.4
E		1	7		8	3.7
ESE		1			1	.5
SE						
SSE		1			1	.5
S		6			6	2.6
SSW		4			4	1.8
SW		4			4	1.8
WSW		11			11	5.0
W		15			15	6.9
WNW		16	2		18	8.2
NW		35	4		39	17.8
NNW		30	11	1	42	19.2
Calm	48				48	21.9
Tot. Freq.	48	145	25	1	219	
Percent Frequency	21.9	66.2	11.4	.5		100.0

TABLE 3m. Distribution of surface winds coincident with fog at Cape Kennedy, Florida. DECEMBER

Month	Normal	Percentage Frequency
January	2.68	5.10
February	3.04	5.92
March	4.48	7.11
April	2.58	4.14
May	2.05	2.99
June	4.81	5.29
July	4.73	3.63
August	4.83	4.64
September	7.33	7.92
October	6.20	7.25
November	2.40	3.24
December	1.65	4.45
Total Inches	46.83	5.14

TABLE 4. Normal rainfall in inches by months and percentage frequency of rainfall occurrence at Cape Kennedy, Florida.

LOCAL TIME	J	F	M	A	M	J	J	A	S	O	N	D
00	0.0	0.4	0.8	0.8	1.2	1.7	1.6	2.8	0.8	0.0	0.0	0.4
01	0.0	0.9	0.8	0.0	0.4	0.4	0.4	3.6	1.7	0.4	0.4	0.0
02	0.0	0.0	0.8	0.0	0.4	1.2	1.2	2.8	1.7	0.8	0.4	0.0
03	0.0	0.0	0.4	0.0	0.4	2.1	0.4	2.4	1.2	1.2	0.4	0.4
04	0.0	0.0	0.4	0.0	0.0	0.4	0.4	2.0	0.8	1.2	0.4	0.4
05	0.0	0.0	1.2	0.0	0.4	0.0	0.4	1.2	0.4	0.8	0.0	0.0
06	0.0	0.0	1.2	0.0	0.4	0.8	0.0	3.1	0.8	0.7	0.0	0.0
07	0.0	0.4	0.4	0.0	0.0	0.7	0.3	2.1	1.4	0.7	0.4	0.0
08	0.0	0.4	0.0	0.3	0.0	0.7	0.3	0.7	1.1	0.4	0.4	0.0
09	0.4	0.0	0.7	0.3	0.0	0.7	0.7	0.7	1.4	0.4	0.4	0.4
10	0.4	0.0	0.7	1.0	0.7	0.4	0.0	2.1	1.4	0.4	0.4	0.4
11	0.4	0.4	0.7	0.3	0.7	2.5	3.2	4.8	1.4	1.1	0.4	0.0
12	0.0	0.0	1.9	0.0	1.7	6.1	6.7	8.7	1.5	2.1	0.0	0.0
13	0.4	0.4	1.5	0.3	1.0	11.5	12.7	11.2	4.0	1.8	0.4	0.0
14	0.0	0.0	1.1	1.1	4.1	14.7	15.7	11.2	6.6	1.1	0.0	0.0
15	0.0	0.0	1.1	2.1	5.2	13.7	16.6	12.3	6.2	2.2	0.4	0.0
16	0.4	0.8	1.2	3.6	5.9	13.6	20.7	12.1	9.1	1.6	0.8	0.0
17	0.0	0.9	0.8	2.9	6.8	11.6	18.0	8.9	8.3	2.8	1.1	0.0
18	**0.4**	**0.0**	**1.6**	**2.5**	**9.3**	**8.3**	**14.4**	**9.7**	**6.2**	2.4	1.1	**0.0**
19	0.0	0.0	3.2	1.7	5.7	5.8	11.8	7.2	6.2	2.4	0.4	0.4
20	0.4	0.0	2.0	1.2	4.8	5.4	5.6	5.6	4.2	2.0	0.8	0.0
21	0.0	0.4	1.6	0.8	4.0	3.7	5.2	4.4	2.5	0.8	0.8	0.0
22	0.0	0.9	2.0	2.1	3.2	1.2	2.8	4.4	3.3	0.8	0.8	0.4
23	0.0	0.4	1.2	1.2	1.6	0.8	0.2	2.8	1.2	0.4	0.4	0.0

TABLE 5a. Hourly percentage frequency of thunderstorm occurrence by month at Cape Kennedy, Florida.

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Percentage Frequency	0.1	0.3	1.1	0.9	2.4	4.5	5.8	5.2	3.1	1.2	0.4	0.1	2.1

TABLE 5b. Monthly percentage frequency of thunderstorm occurrence at Cape Kennedy, Florida

Time	ΔT ≥ +3°F	+3°F > ΔT ≥ 0°F	0°F > ΔT ≥ -3°F	ΔT ≤ -3°F
	July, August and September 1961 (221 observations)			
Sunrise	50	46	4	0
Noon	0	0	50	50
Sunset	4	83	13	0
Midnight	26	72	2	0
	October and November 1961 (230 Observations)			
Time	ΔT ≥ +3°F	+3°F > ΔT ≥ 0°F	0°F > ΔT > -3°F	ΔT ≤ -3°F
Sunrise	32	64	2	2
Noon	0	4	86	10
Sunset	8	85	7	0
Midnight	23	69	8	0
	December 1961 and January 1962 (157 observations)			
Time	ΔT ≥ +3°F	+3°F > ΔT ≥ 0°F	0°F > ΔT > -3°F	ΔT ≤ -3°F
Sunrise	22	61	17	0
Noon	0	5	95	0
Sunset	5	85	10	0
Midnight	10	87	3	0

TABLE 6. Percentage frequency of occurrence of ΔT by time of day at Cape Kennedy (From AFCRL 63-791 (II)).

NORMAL			EXTREMES		MEAN	Standard	Vapor	
ax	Min	Mean	High	Low	Dew Point (Td)	Deviation (Td)	Pressure (lbs/in^2)	Month
.6	52.0	60.5	83	30	53.3	10.9	.410	JAN
.5	53.9	62.5	85	30	55.5	10.8	.448	FEB
.4	56.9	64.9	87	34	56.9	10.1	.447	MAR
.7	62.1	69.6	89	46	60.7	7.8	.535	APR
.1	67.9	75.2	95	54	67.1	5.4	.669	MAY
.8	72.1	79.2	99	58	72.1	3.3	.794	JUN
.7	74.0	81.1	95	66	74.2	2.0	.852	JUL
.6	74.0	81.0	95	66	74.6	2.3	.863	AUG
.9	74.1	80.2	95	66	73.3	2.7	.826	SEPT
.4	69.4	75.6	91	50	67.9	6.5	.688	OCT
.6	61.1	68.5	87	30	61.1	9.6	.542	NOV
.1	54.0	62.3	85	26	54.9	11.0	.434	DEC
.6	64.2	71.6	99	26	64.3	10.9	.607	ANNUAL

TABLE 7. Surface dry-bulb and dew point temperature summary for Cape Kennedy, Florida.

Wind Direction	0-150	151-350	351-550	551-1050	1051-2050	2051-3050	3051-10500	10501-20500	20501-30500	>30500 & UNLIM	<6/10 Clouds
N	0.5	0.3	0.7	2.1	4.2	5.5	14.9	6.8	0.6	8.7	55.6
NNE	0.1	0.0	0.2	0.5	0.9	5.3	14.8	6.3	0.2	11.1	60.5
NE	0.0	0.1	0.0	0.2	1.3	5.8	15.1	6.9	0.7	12.0	57.8
ENE	0.0	0.0	0.1	0.1	1.5	4.5	17.4	7.0	0.4	14.0	55.0
E	0.0	0.0	0.0	0.3	1.9	4.3	15.5	7.4	0.4	15.4	54.8
ESE	0.0	0.0	0.0	0.2	1.7	3.5	11.2	7.9	0.7	17.1	57.6
SE	0.0	0.0	0.0	0.1	1.4	3.5	10.6	8.7	0.9	17.9	56.8
SSE	0.0	0.0	0.1	0.4	1.6	3.4	11.5	9.8	1.5	18.5	53.3
S	0.1	0.1	0.1	0.7	2.3	3.8	13.6	11.3	1.2	15.7	51.0
SSW	0.1	0.1	0.1	1.6	2.6	4.8	12.5	11.7	1.1	13.0	52.5
SW	0.0	0.1	0.3	0.8	2.5	5.1	13.5	10.0	1.1	13.7	52.8
WSW	0.1	0.2	0.7	1.8	3.6	4.6	12.5	10.2	0.9	11.3	54.0
W	0.1	0.5	0.6	1.3	2.5	5.2	9.8	6.2	0.6	9.6	63.7
WNW	0.3	0.6	1.1	1.7	4.1	4.7	9.7	4.9	0.3	6.4	66.3
NW	0.6	1.0	1.3	3.2	3.4	4.2	9.9	4.4	0.6	6.0	65.4
NNW	0.6	1.1	1.8	5.2	5.5	5.5	11.8	6.9	0.4	7.6	53.7
Calm	0.3	0.1	0.2	0.3	1.8	3.0	11.6	10.2	1.6	11.9	59.0
Percent of Total	0.2	0.2	0.4	1.2	2.5	4.4	12.7	7.9	0.8	12.8	56.9

TABLE 8. Annual percentage frequency of ceiling height (feet) versus surface wind direction at Cape Kennedy, Florida.

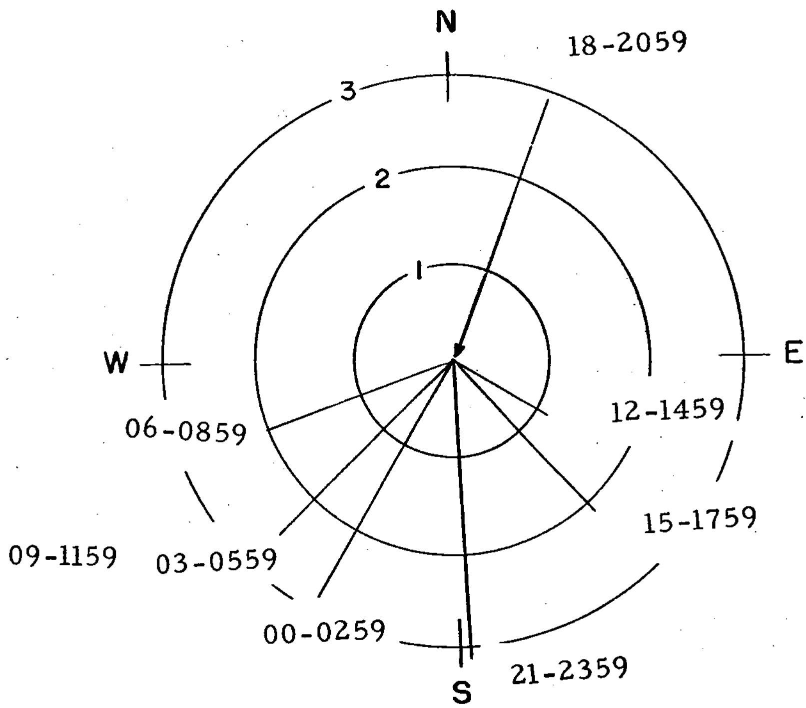


Figure 1a. Mean vector surface winds during the course of the day for the month of March at Cape Kennedy, Florida. Each circle equals one knot.

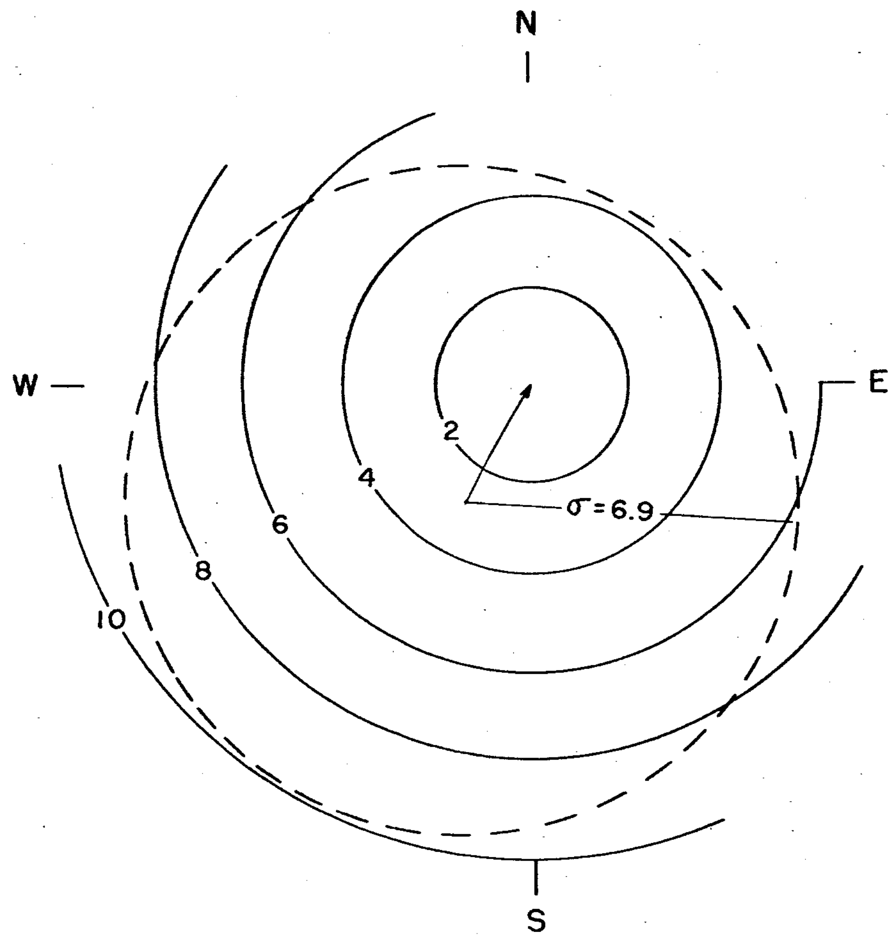
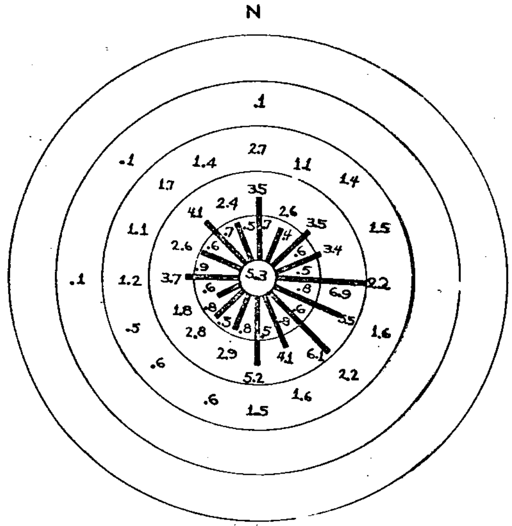


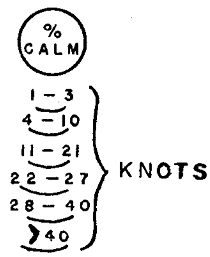
Figure 1b. Mean vector surface wind and vector standard deviation, March, 0000-0259 LST, Cape Kennedy, Florida. Each solid circle equals two knots. Approximately sixty-three percent of all wind observed during this time period originate within the dashed circle.



5.3	10.3	61.0	22.8	.5	.1

Figure 2a. Surface wind distribution at Cape Kennedy - ANNUAL

LEGEND:

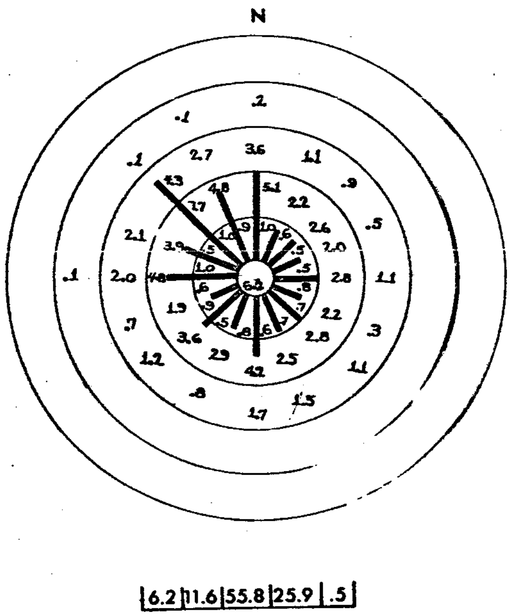


SPEED FREQUENCY: Printed figures represent percentage frequency of wind observed from each direction within each speed interval. The figure appears either at the end of the wind bar or adjacent to and in a clockwise direction from the bar.

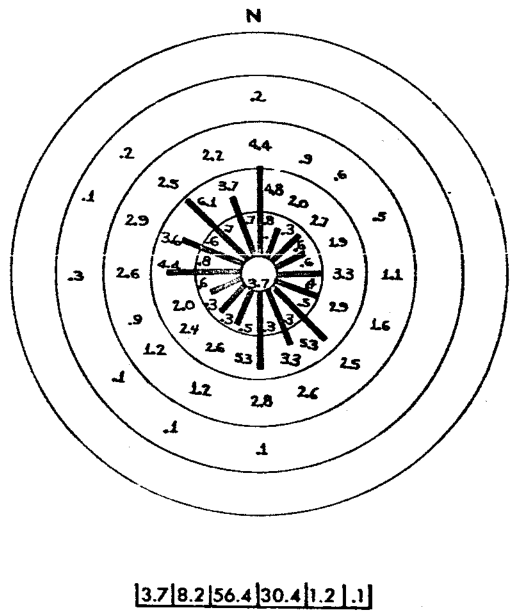
DIRECTION FREQUENCY: Bars indicate percentage frequency of wind observed from each direction. Each circle, starting from the inside circle, equals 5 percent.

CALM	1 - 3	4 - 10	11 - 21	22 - 27	28 - 40	>40

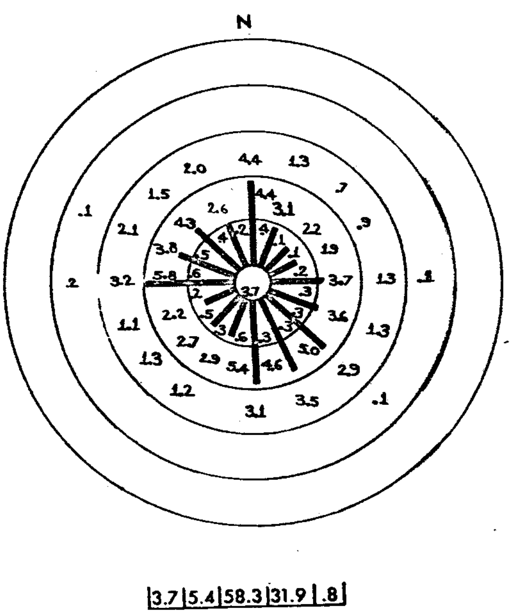
The table below each wind rose provides percentage frequency of wind speed for each indicated speed range.



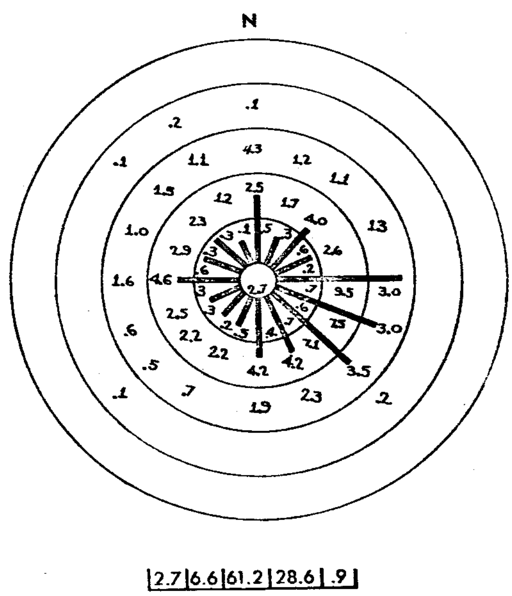
JANUARY



FEBRUARY



MARCH



APRIL

Figure 2b. Surface wind distribution at Cape Kennedy. See legend on Figure 2a.

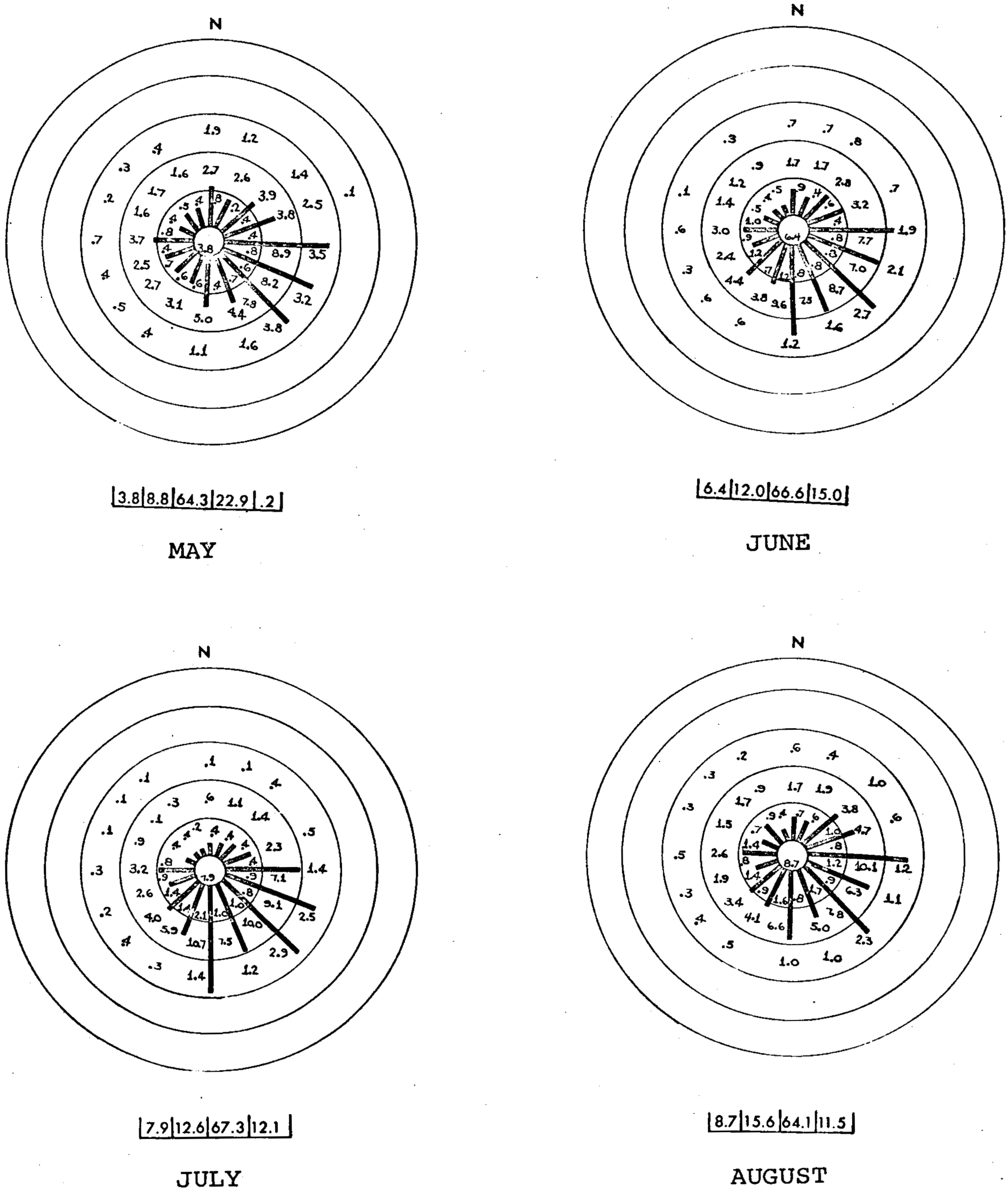
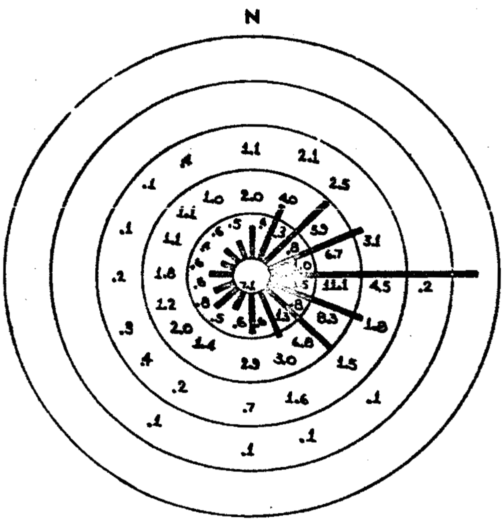
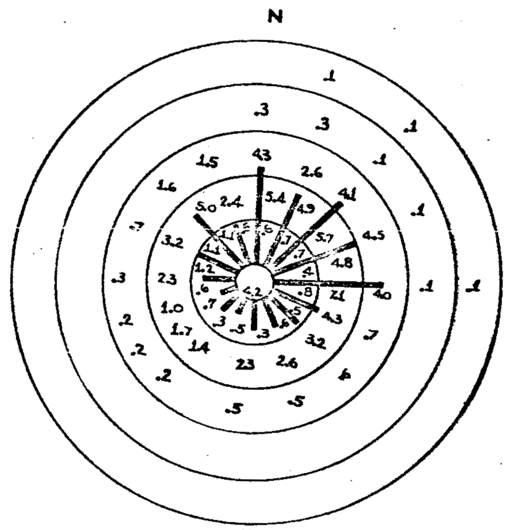


Figure 2c. Surface wind distribution at Cape Kennedy. See legend on Figure 2a.



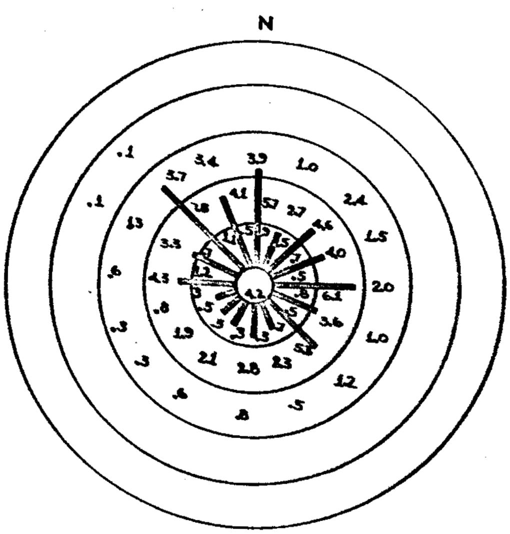
|7.1|11.2|60.2|20.7|.7|.2|

SEPTEMBER



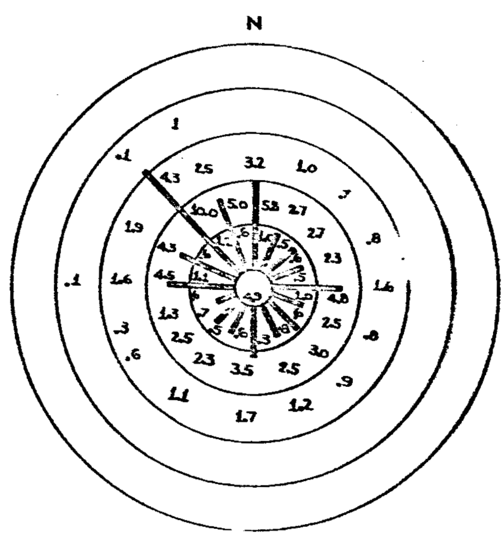
|4.2|10.7|57.2|26.5|1.1|.3|

OCTOBER



|4.2|9.9|61.1|24.5|.3|

NOVEMBER



|4.9|11.2|59.5|24.1|.5|

DECEMBER

Figure 2d. Surface wind distribution at Cape Kennedy. See legend on Figure 2a.

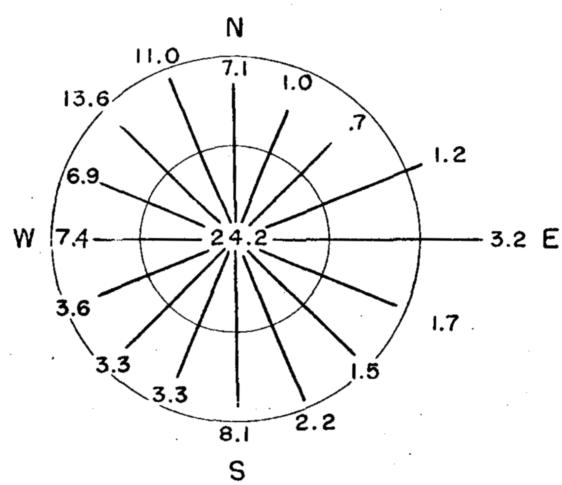


Figure 3. Annual distribution of surface winds coincident with the occurrence of fog at Cape Kennedy, Florida. Each circle equals five knots. Percentage frequency of wind occurrence is indicated by figures appearing at the end of the wind bar, or in the center in the case of calms.

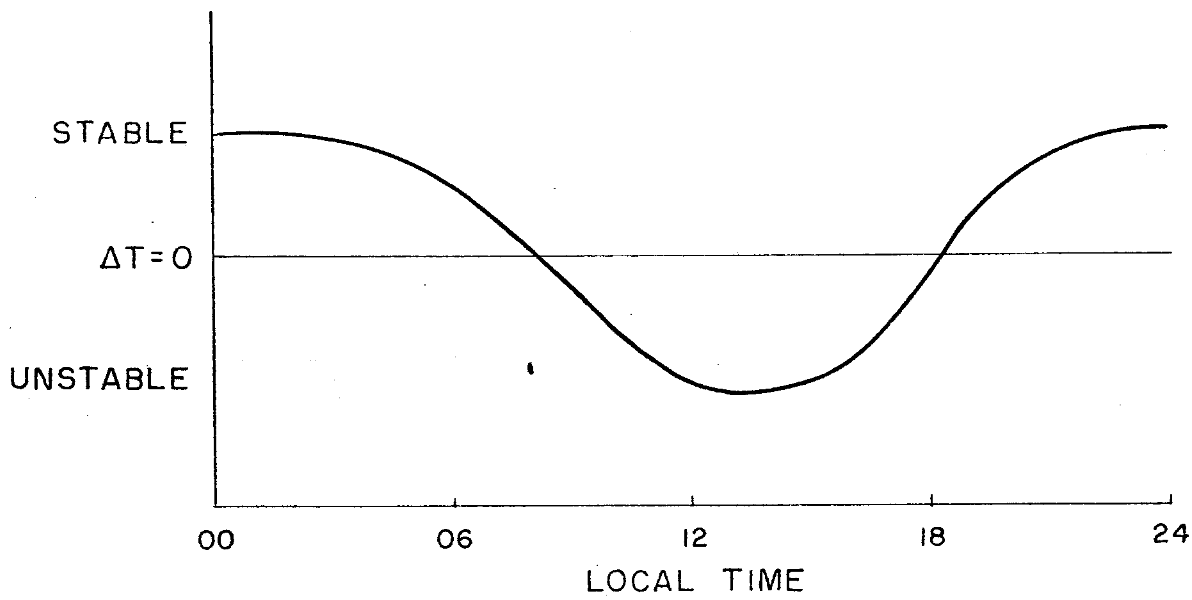
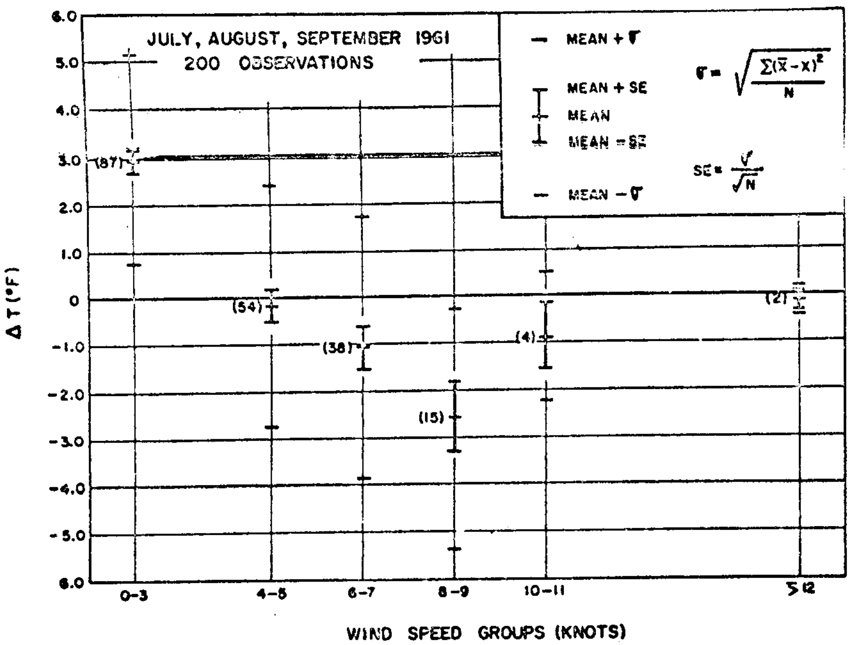
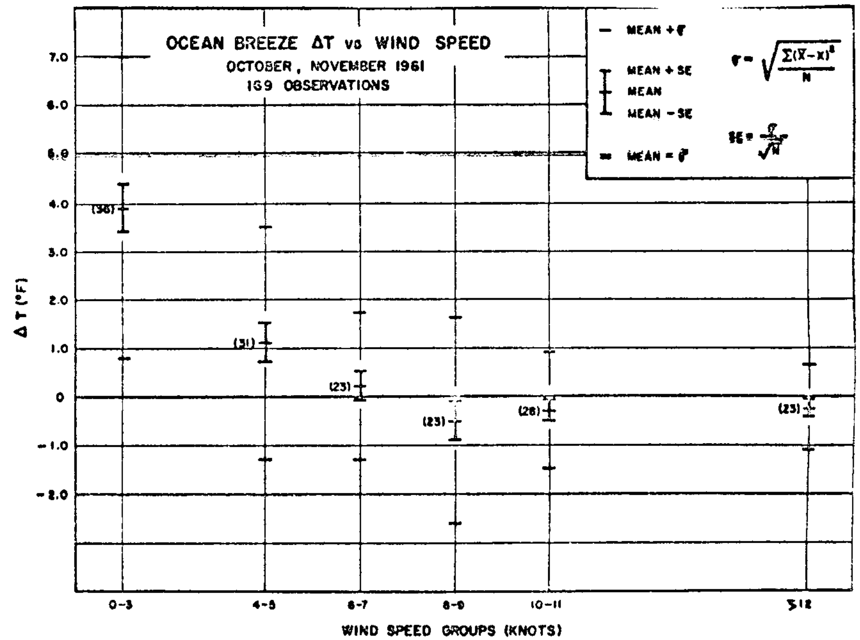


Figure 4. Schematic depiction of stability related to time of day. Solid line is the temperature difference between 54 feet and 6 feet.





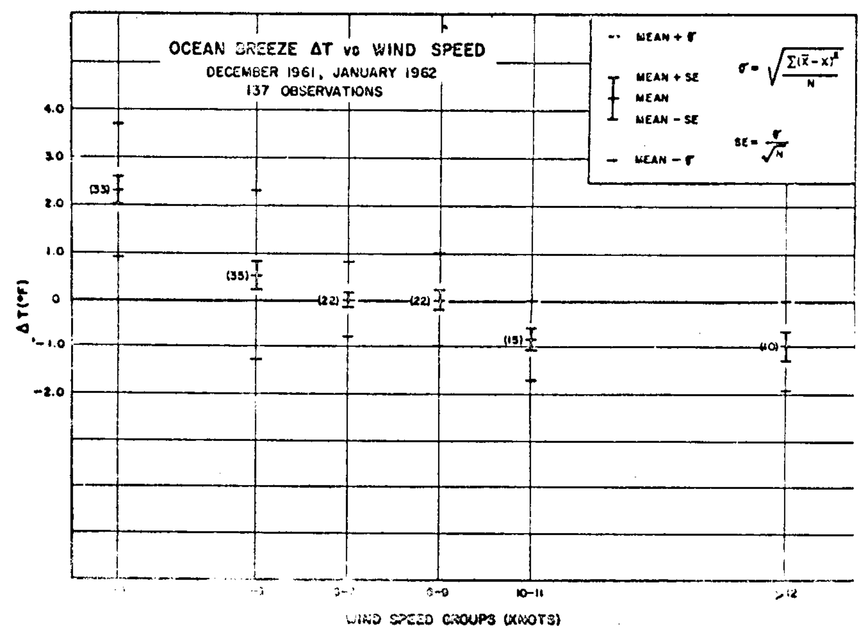


Figure 5. Distribution of temperature difference (ΔT) between 6 and 54 feet at Cape Kennedy as a function of wind speed. A positive ΔT indicates temperatures warmer at the higher elevation (From AFCRL-63-791 (II)).